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CHANCE AND DETERMINISM IN EVOLUTION: TEACHERS' CONCEPTIONS IN 21 COUNTRIES

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Abstract

While stochastic processes are central in biology, they have only recently begun to be introduced at school, where biology is often associated with deterministic processes.

To analyze teachers' conceptions of the role of determinism and chance in evolution, we conducted a large survey in 21 countries: 8 078 in-service and pre-service teachers (in Primary Schools and in Secondary Schools teaching biology or language) filled out the BIOHEAD-Citizen questionnaire, including 14 questions on Evolution and 17 on personal opinions.

We found important differences among the countries. While the importance of natural selection in species evolution is widely accepted, it is not the case for chance. When chance is not associated with evolution (*When a couple has already had two girls, the chances that their third child be a boy are higher*), more teachers recognize the role of chance. On the contrary, a significant number of teachers think that God is very important or important in species evolution. Nevertheless, several of them (particularly biologist teachers) are simultaneously evolutionist and creationist.

In half of the countries, we found significant differences between biologist teachers and their colleagues, biologist teachers being more convinced of the importance of chance, natural selection and evolution.

Key words: Chance, Evolution, Creationism, Teachers' Conceptions, International survey.

1 – Biological topic

Since Descartes (17th Century), living organisms have been compared to machines. Creationist publications reproduce this way of thinking, comparing any organism with a machine such as a watch and claiming that they know the watchmaker (God).

Darwinism (and subsequently neo-Darwinism) contradicts this determinist point of view. Stochastic processes are involved in the differentiation of new structures, which are then selected by natural selection, or conserved as neutral.

Furthermore, new trends in biology promote the idea of a cellular Darwinism (Kupiec 2008, Kupiec et al 2009): during embryonic development, each cell fluctuates randomly between different states and stabilizes according to its interactions with neighbouring cells, by natural selection. From the growing number of new data in biological research showing the key role of stochastic processes, several authors suggest “*the end of determinism in biology*” (Paldi & Coisne 2009), and philosophers are distinguishing several kinds of determinism (Gayon 2009).

The philosopher of biology Gayon (1997) defined three categories of meanings for the concept “hasard” (in French), more or less corresponding to the concept of “chance” in English: (1) An unpurposed and unpredictable event, without design but which can be *a posteriori* useful. (2) A chancy event, by random, but which can be predictable by the laws of probability. If you toss a coin, it will fall by chance on its “head” or on its “tail”. If you toss it 10 000 times, it will fall on its head 50% of the time and 50% on its tail: this result is predictable and reproducible. (3) Fortuitous events, by chance because they are not predictable inside a theory, they are too complex: chance is here contingent to a theoretical system.

Concerning the five levels of biological evolution, mutations and macro-evolution are related to the meaning (1), the genetic drift with the meaning (2) and the levels of genome as well as of ecosystems with the meaning (3)

Consequently, linked to the meaning (2), chance does not mean lack of reproducibility: random events at the molecular level may lead to cellular structures that are ordered and reproducible. Early in 20th Century, quantum physics, with the principle of Heisenberg, showed that stochastic processes produce apparent order in physical and chemical phenomena. At the same time, taught biology became more determinist, taught genetics being mainly been centred on the determinism of the phenotype by the genotype (Forissier & Clément 2003, Castéra et al. 2008, Clément & Castéra 2013). This reductionist view has decreased since the end of 20th Century with “*the end of everything is genetic*” (Atlan 1999), the notions of cerebral epigenesis (also called Neuronal Darwinism: Changeux 1983, Edelman 1987) and of epigenetics (interaction between genes and their environment to explain the emergence of phenotypes: Lewontin 2000, Jacquard & Kahn 2001, Wu & Morris 2001, Morange 2005). The present revival of creationist views, including the intelligent design, is a return to the past, promoting deterministic explanations that are out-dated in biology. To day, the neo-Darwinian explanation of evolution is not only accepted but also considered as central in biology (Dobzhansky, 1973).

Our goal is to analyse if these new paradigms in biological research are now being introduced in biology teaching. Biological knowledge is universal, but the way it is taught is often different, depending of the social context and the teachers’ values. We will analyse this interaction between taught science and society, using a comparative approach among several contrasting countries.

2 - Theoretical background

We analyze here teachers' conceptions, because teachers are a key step in the didactic transposition of new knowledge at school (Chevallard 1985, Clément 2006). We are particularly interested in the DTD (Delay of Didactic Transposition: Quessada & Clément 2007), i.e. the delay between the emergence of new concepts in research (Darwinian processes, importance of chance, decrease of determinist views, ...) and their introduction into the taught science.

We can define four types of DTD, if we analyze: (1) the syllabuses, (2) the textbooks, (3) the teachers' conceptions and (4) the sequences of teaching. The syllabus and textbooks have already been analyzed in several countries for the topic Evolution (e.g. Quessada et al 2008, Quessada 2008): they are still to be analyzed concerning a clearer presence of stochastic processes. Sequencing by teachers is analyzed in some countries, such as Tunisia where teaching evolution is problematic (Aroua 2008). The present paper analyzes only the teachers' conceptions in several countries.

We used four levels of conceptions (Clément 2010, Table 1):

- Situated conception, expressed by somebody in a precise situation (here each question of the used questionnaire).
- Conception, as the convergence of several situated conceptions (here the convergence from a set of questions dealing with the same topic).
- Social representation (Moscovici 1984) when the same conception is held among the members of a social group (also called collective representation by Durkheim 1889).
- System of conceptions when there is a significant correlation between several social representations.

Table 1 – Different types of conceptions, explained for the analysis of answers to a questionnaire (translated from Clément 2010, and modified)

	Individual level	Collective level
Situated Conceptions	When somebody answers to a precise question in a precise situation (as a question of a questionnaire)	When several persons, placed in a precise situation, answer in the same way (e.g. answer identically to a precise question of a questionnaire)
Conceptions related to a topic	When somebody answers with coherence to several questions (= different situations) related to the same topic	When the individual conceptions related to a topic are shared inside a social group: “ social representations ” (Moscovici 1984), “Collective representations” (Durkheim 1898)
System of conceptions	When several conceptions (social representations) are correlated, or are correlated with political, social or religious opinions (e.g. the Principal Component in a PCA, or in a Co-Inertia Analysis)	

We also use the KVP model (Clément 2004, 2006, 2010), to analyze these conceptions as possible interaction between scientific knowledge (K), Values (V) and social practices (P).

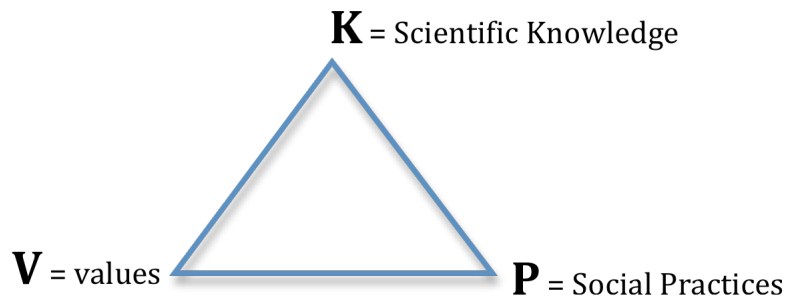


Figure 1 – The KVP model (translated from Clément 2004)

For instance deterministic conceptions can be supported by out-dated scientific knowledge (K) but also by values (V) as fatalism, and social practices (P) as housekeeping by women and not by men.

3 - Key objectives

We focus the present work on teachers' conceptions related to the role of chance and determinism in the evolutionary processes. The degree of acceptance or reject of creationism (as a deterministic process of evolution) is compared to the degree of considering the importance of some processes of evolution as chance and natural selection.

The possible interaction between the teachers' conceptions and their national socio-cultural context is analyzed by a comparison among different countries.

Related to the KVP model, we mainly identify if the teachers' scientific knowledge is up-to-date or out-dated, trying to understand the resistance of some out-dated knowledge if rooted in values and practices. In each country, we compare the conceptions of teachers trained in biology at University, with conceptions of their colleagues, to identify the possible effect of teachers' training in biology.

4 - Research design and methodology

We used a long questionnaire, built by the BIOHEAD-Citizen project (*European Research Project: Specific Targeted Research n° CIT2-CT2004-506015, FP6, Priority 7*), tested and validated over two years (Clément & Carvalho 2007). Here, we use the answers to two sets of questions: on Evolution (14 questions), and on personal political or religious opinions (17 questions: for instance the question P12b, illustrated below in the figure 7).

The 14 questions related to Evolution have several goals:

- To identify if the teachers' conceptions are more or less creationist (evolution being determined by God) or evolutionist (only natural processes): 5 questions (including B48 and B28 illustrated by the figures 6 and 7), with the possibility, e.g. in the question B28 (figure 7) to tick the item 3 which is at the same time evolutionist and creationist. In this last question, the items 1 and 2 are evolutionist, the first one being more dogmatic while the item 2 is mentioning God (“...*without considering the hypothesis that God created humankind*”).
- To identify if, for the teachers, evolution is or not goal-ended, determined or not by a project (the first meaning of chance defined above, in the introduction): 2 questions.
- To identify the degree of teachers' knowledge related to the biological processes of evolution (origin of new species: macro-evolution): 6 questions, including B42 (importance of chance: Figure 3) and B43 (importance of natural selection: figure 4).

- To identify the teachers' knowledge related to elementary stochastic processes which are not directly related to evolution: "*When a couple has already had two girls, the chances that their third child be a boy are higher*" (question A31: Figure 5).

These questions are not related to all the possible meanings of "chance", as exposed above, but are focused on the degree of acceptance or reject of evolution and of chance in the evolutionary processes. The questionnaire is submitted in several contrasting countries to identify the link between these degrees of acceptance or reject and the socio-cultural context of each country.

Countries were chosen from their diversity: 13 were involved in the BIOHEAD-Citizen project, and 8 others are new (data obtained in 2009-2012): Australia, Brazil, Burkina Faso, Cameroon, Denmark, Georgia, Serbia, Sweden (figure 2)

EUROPE	Europe	North	Finland (306) Sweden (377) Denmark (259) Estonia (182)
	Europe	East	Hungary (334) Romania (273) Serbia (314) Georgia (296)
	Europe	West	France (732) Italy (559) Portugal (350) Cyprus (322)
OUTSIDE EUROPE	Arabic	North Africa	Morocco (330) Algeria (223) Tunisia (753)
		Middle Esat	Lebanon (722)
	Africa	West Africa	Senegal (324) Burkina Faso (296) Cameroun (523)
	Other Continents		Australia (201) Brazil (402)

Figure 2 – Sampling in the 21 countries: in blue are the countries involved in the Biohead-Citizen project (data collected in 2006-2008); the other countries are shown in red (data collected in 2009-2012)

Five other countries involved in the Biohead-Citizen project (Germany, U.K., Poland, Lithuania and Malta) are not included in the present work, because they decided to use a shorter version of the questionnaire, omitting the "part B". Most of the teachers' responses analyzed in the present work come from part B of the questionnaire.

After the end of the Biohead-Citizen project, the choice of new countries was done for specific reasons. For instance, concerning the countries outside Europe, we initially had only Muslim countries (North Africa, Senegal and Lebanon, including 1/3 of Lebanese teachers who were Christian). Subsequently, we decided to extend our sampling outside Europe to countries with a high proportion of Christian teachers (Burkina Faso and Cameroon in Africa; Australia and Brazil to start an expansion to other continents). In Europe, we chose two mainly Orthodox countries (Serbia and Georgia) and two new Scandinavian countries (with mainly Protestant or Atheist / Agnostic teachers: Denmark and Sweden).

Three categories of teachers answered the questionnaire in each country:

1/3 in Primary school,
 1/3 in Secondary schools teaching Biology and
 1/3 in Secondary schools teaching the national Language.

For each category, half are in-service teachers and the other half are pre-service teachers (the last year of training before teaching). The total number by country is indicated in Figure 1 (total = 8 078).

The data are analyzed by classical statistical tests (such as χ^2), but also by multivariate analyses using the “R” software (Munoz et al 2007, 2009), but we will not include all the detailed results in the present work.

5 – Findings

Figure 3 shows the responses of teachers to the question B42 related to the importance of chance in species evolution. For the following figures, we separated biology teachers (teaching biology in secondary school, but also some of the teachers in primary schools, when they were trained in biology at University) and other teachers (with no training in biology at University).

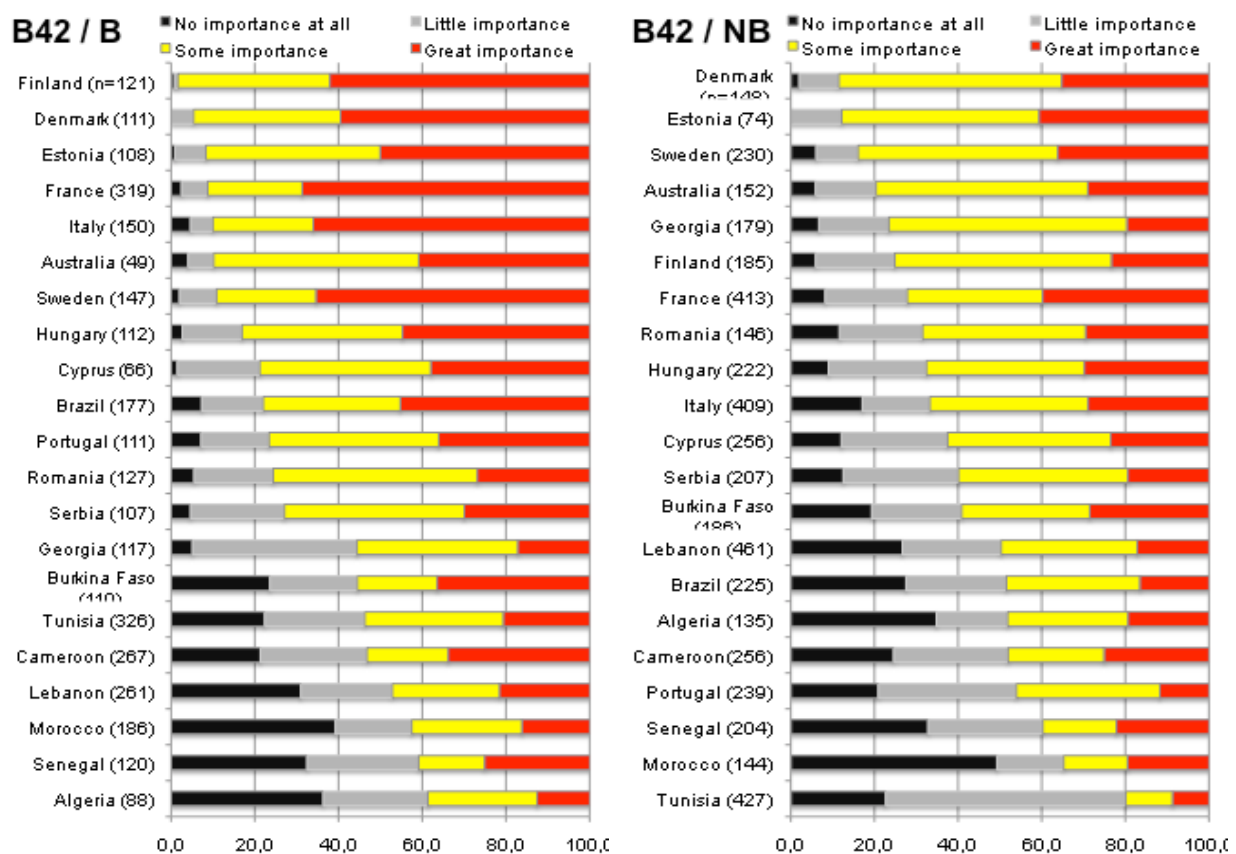


Figure 3 – Biologist (B) and Non-Biologists (NB) Teachers’ answers (grouped by country, N = 8078) to the question B42: *Importance of Chance in species Evolution*: (red) “Great importance”; (yellow) “Some importance”; (grey) “Little importance”; (black) “No importance at all”.

The difference between biology teachers and non-biology teachers (Figure 3) is significant in 12 countries (Brazil, Cyprus, Denmark, Finland, France, Georgia, Hungary, Italy, Portugal, Serbia, Sweden, Tunisia), showing an effect of studying biology at University. Nevertheless, the percentage of biology teachers thinking that chance is not important in species evolution,

remains high: between 61% and 40% in 8 countries (Georgia, Burkina Faso, Tunisia, Cameroon, Lebanon, Morocco, Senegal and Algeria), and >20% in 5 other countries (Cyprus, Brazil, Portugal, Romania and Serbia).

Are these high proportions linked to the topic evolution? We investigated this by looking at the responses related to the main Darwinian process: natural selection.

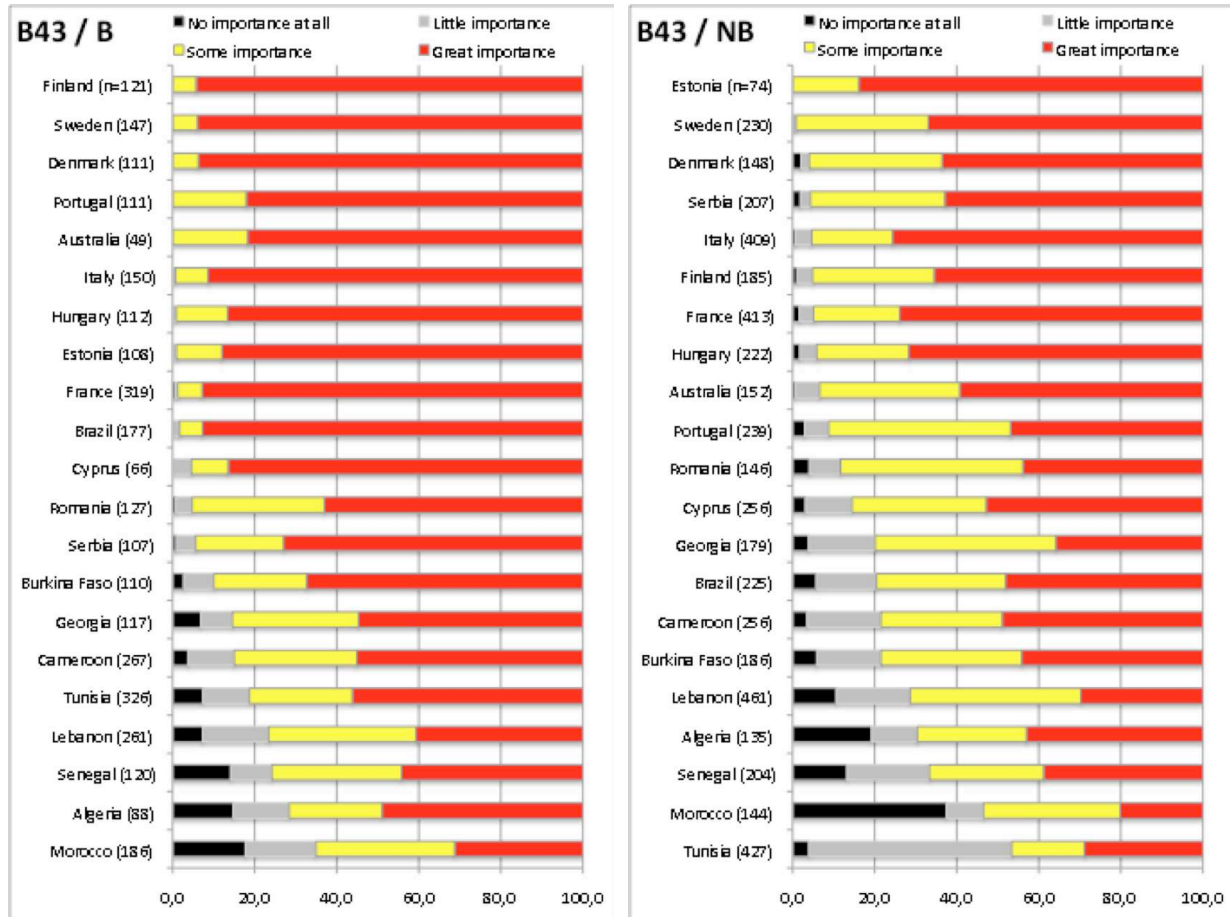


Figure 4 – Biologist (B) and Non Biologists (NB) Teachers' answers (grouped by country, N = 8078) to the question B43: *Importance of Natural Selection in species Evolution*: (red) "Great importance"; (yellow) "Some importance"; (grey) "Little importance"; (black) "No importance at".

Figure 4 clearly shows that most of the teachers, in the 21 countries, ticked the boxes "great importance" of natural selection (red in the Figure) or "some importance" (yellow in the Figure): much more, in each country, than for the importance of chance.

Biologists are particularly convinced of this importance: only in the 5 African countries of our sample, as well as in Lebanon and in Georgia, between 10% (Burkina Faso) and 37% (Morocco) of biology teachers chose little or no importance of natural selection. In 13 countries, less than 5% ticked little or no importance, including 9 countries with 0%. In contrast, for the importance of chance, only in one country (Finland) less than 5% of biology teachers ticked no or little importance, and in 13 countries from 11% (Cyprus) to 61% (Algeria).

Non-biologist teachers are just a little less convinced of the importance of natural selection than their biologist colleagues: the difference between biologist and non-biologist teachers is

significant ($p < 0.01$; except Lebanon, $p = 0.02$) in most of the countries, except in Cameroon, Senegal and Algeria (where evolution is not taught or of very few: Quessada et al 2008, Quessada 2008), and also in Estonia and Serbia where almost all the teachers know the importance of natural selection. Nevertheless, even for the non-biologist teachers, the percentages selecting no or little importance of natural selection are less than for chance: from 0% to 46% for natural selection (with 14 countries $< 20\%$) while from 11% to 80% for chance (with only 3 countries $< 20\%$).

These results show that (1) when trained in biology, as was the case for chance, more teachers know the importance of natural selection, even when having creationist conceptions (for comparison related to some of these countries, see our published results in Clément & Quessada 2008, 2009, 2012 and below: Figures 6 & 7); and (2) teachers are more reluctant to accept the important role of chance than the important role of natural selection.

Is this last reluctance linked to the topic of evolution, or is it more general? We began to answer this question by analyzing our data related to a question where stochastic processes are not directly linked to evolution: A31 (figure 5).

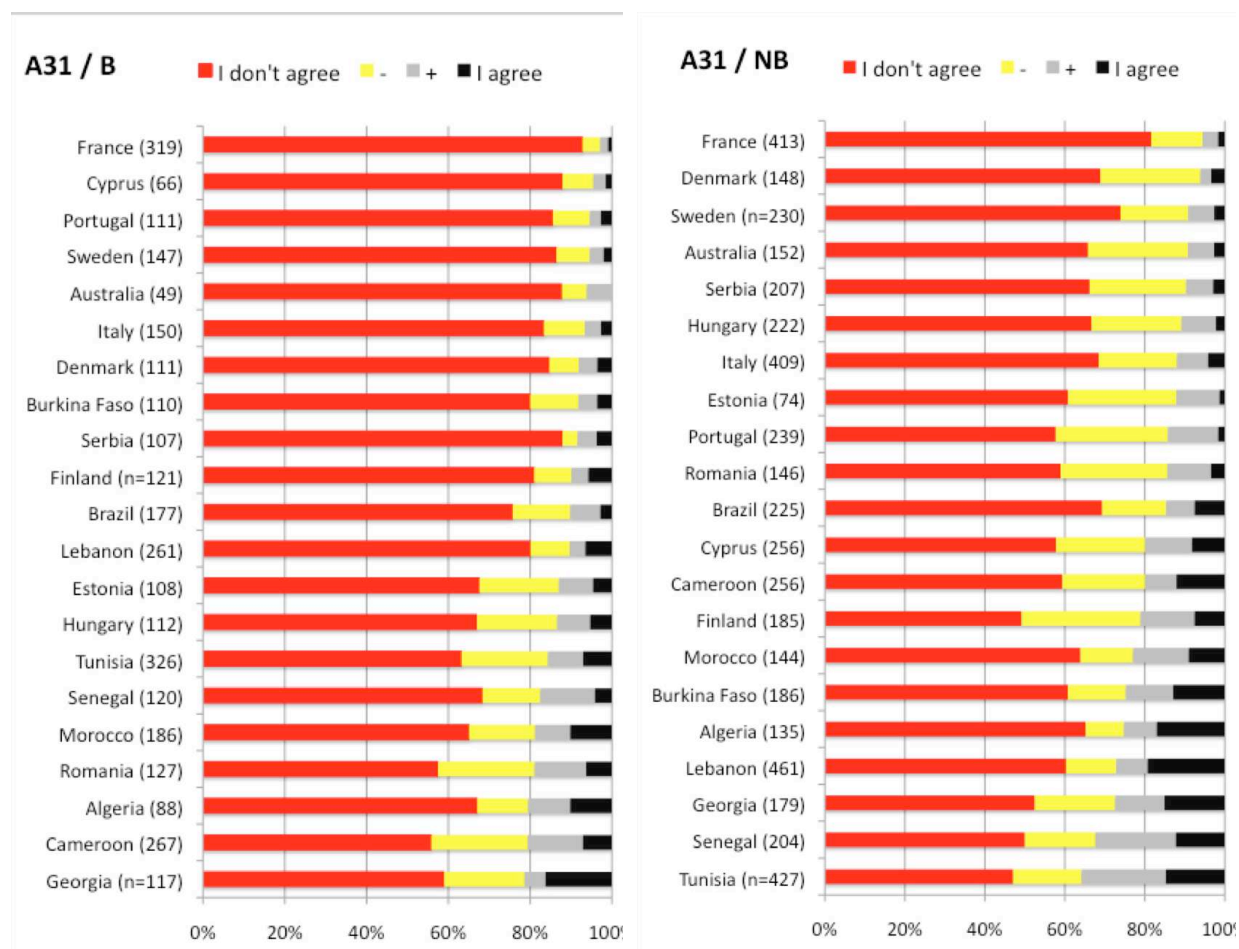


Figure 5 – Biologist (B) and Non-Biologists (NB) Teachers' answers (grouped by country, N = 8078) to the question A31: *When a couple has already had two girls, the chances that their third child be a boy are higher*: (red) "I do not agree"; (yellow) "I rather do not agree"; (grey) "I rather agree"; (black) "I agree".

Figure 5 shows that most of the teachers, happily, disagree or rather disagree with the proposition "*When a couple has already had two girls, the chances that their third child be a boy are higher*": from 79% (Georgia) to 97.2% (France) of biology teachers, and from 64.2%

(Tunisia) to 94.4% (France) for their non-biologist colleagues. The difference between biology and non-biology teachers is significant in 13 countries, showing a better knowledge of stochastic processes after training in biology at University.

More importantly, these data show that the reluctance to accept the importance of chance is much more important when dealing with evolution (question B42, Figure 3) than when dealing with another process as in the proposition A31 (Figure 5):

- For biology teachers, in all the 21 countries, less than 21% did not agree with the role of chance for the question A31, while in 13 countries, 21% to 61.4% did not agree with the importance of chance in the evolution of species (question B42, Figure 3).
- For the non-biology teachers, the disagreement with the importance of chance is between 5.6% (France) to 35.9% (Tunisia) when answering the question A31 (Figure 5), but from 10% (Denmark) to 80% (Tunisia) when answering the question B42 (importance of chance in species evolution: Figure 3).

In consequence, the difficulty teachers have in accepting the importance of chance in biological processes is more important when dealing with evolution. We can go further by analyzing the teachers' answers related to deterministic processes of evolution (Figure 6).

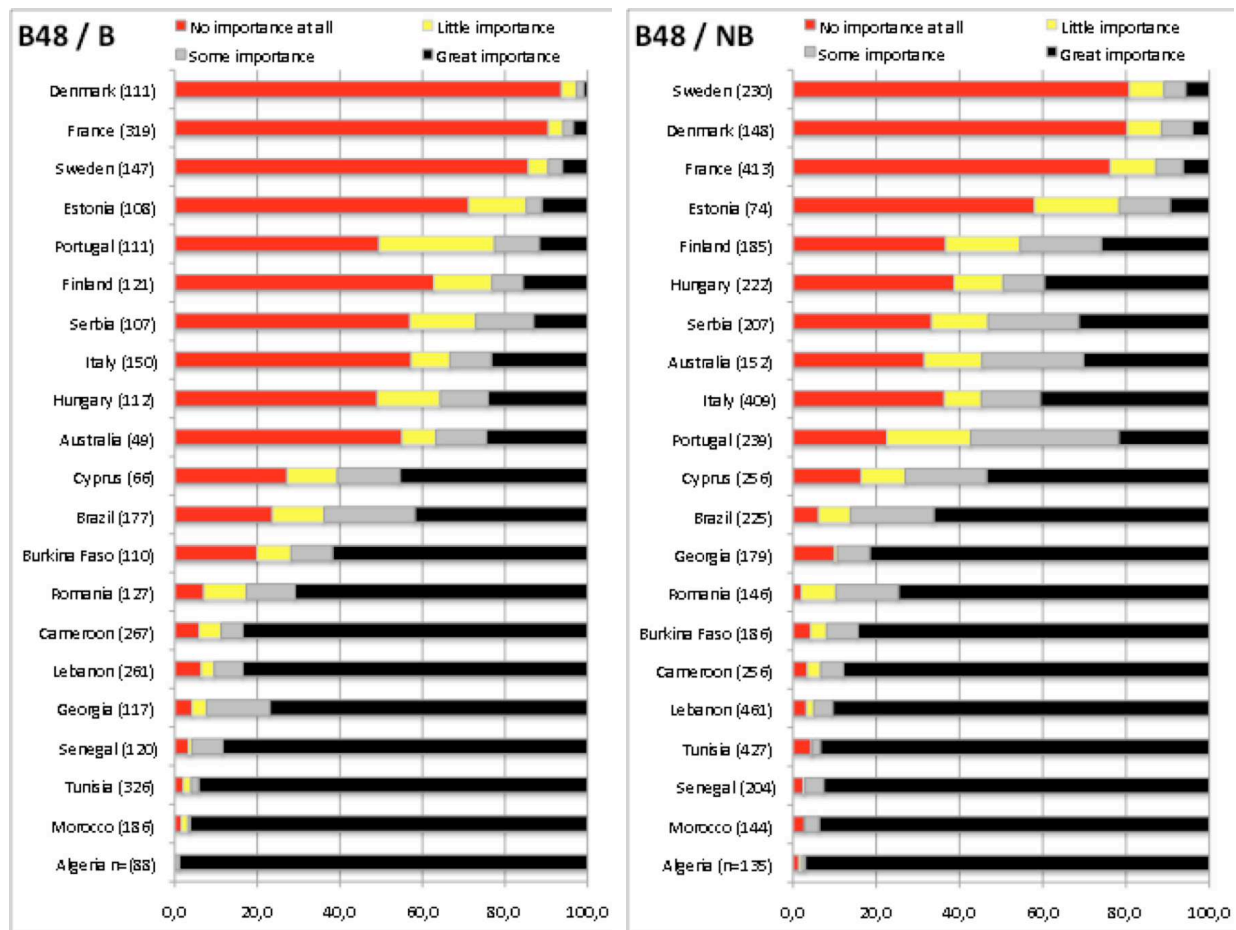


Figure 6 – Biologist (B) and Non Biologists (NB) Teachers' answers (grouped by country, N = 8078) to the question B48: *Importance of God in species Evolution*: (black) "Great importance"; (grey) "Some importance"; (yellow) "Little importance"; (red) "Not important".

The teachers' answers to the question of the importance of God in species evolution (Figure 6) show more distinct differences among countries than the previous questions: for biology

teachers: from 2.7% (Denmark) to 100% (Algeria) of great or some importance of God; as well as for their non-biologist colleagues: from 10.2% (Sweden) to 98% (Algeria). The difference between biology and non-biology teachers is significant in 8 countries (Burkina Faso, Brazil, Denmark, Finland, France, Italy, Portugal and Serbia).

Multivariate analyses show that there is a significant correlation between the answers to the question B48, Figure 6) and the level of practicing religion in each country (question P12b, Figure 7), whatever the religion is (Catholic, Protestant, Orthodox or Muslim), and with several questions related to evolution, as B28 (Figure 7).

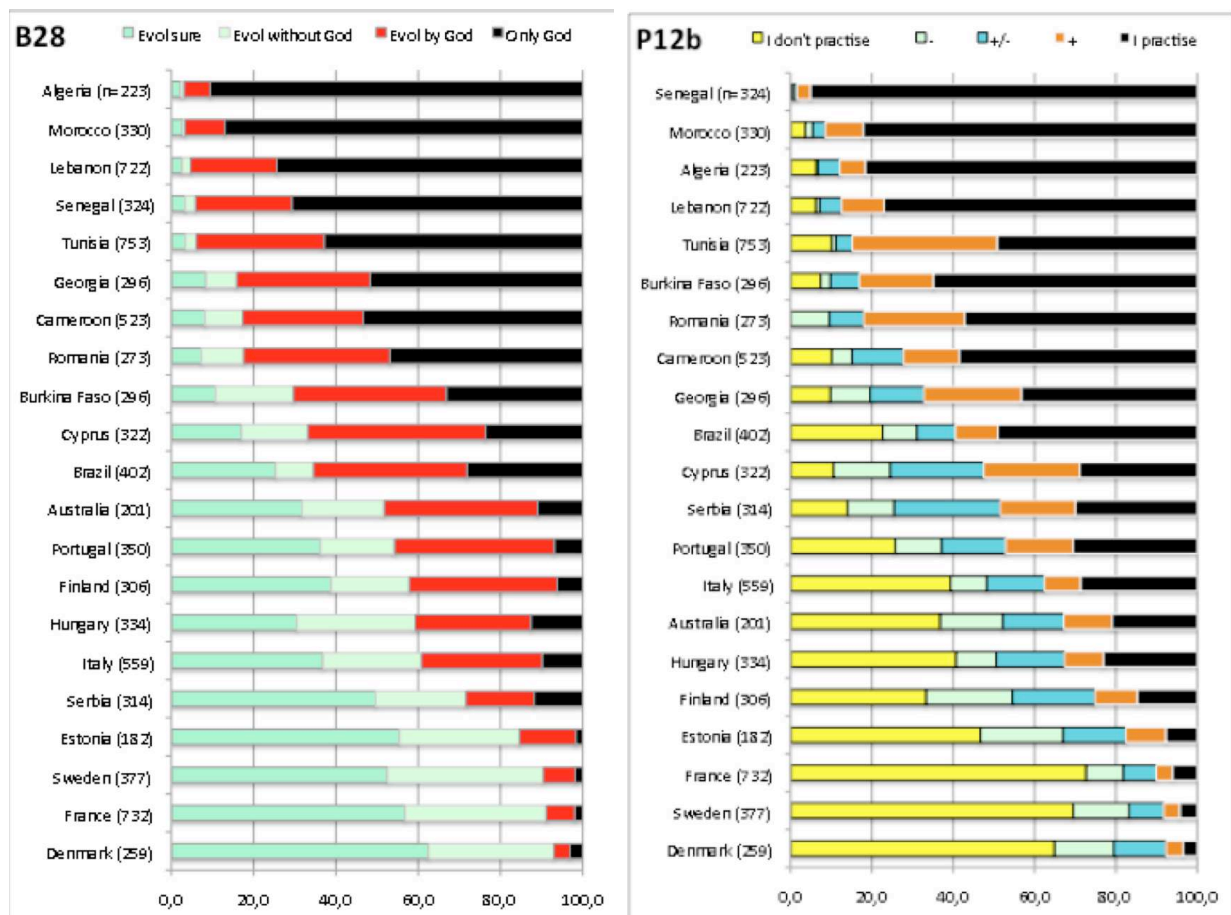


Figure 7 - Teachers' answers to two questions of the questionnaire Biohead-Citizen.

N = 8078 teachers, grouped by countries (21 countries):

B28. Which of the following four statements do you agree with most? Select one sentence:

- ☐ It is certain that the origin of the humankind results from evolutionary processes.
- ☐ Human origin can be explained by evolutionary processes without considering the hypothesis that God created humankind.
- ☐ Human origin can be explained by evolutionary processes that are governed by God.
- ☐ It is certain that God created humankind

P12b: Five boxes between “**I practice religion**” to “**I do not practice religion**”

The comparison between figures 6 and 7 shows that the teachers who practice a religion the most (P12b, Figure 7) also tick great or some importance for the importance of God in species evolution (B48, Figure 6) but select the item 3 or the item 4 to answer the question B28 on the origin of humankind (Figure 7).

While the item 4 is radically creationist “*It is certain that God created humankind*”, the item 3 is at the same time creationist and evolutionist (“*Human origin can be explained by*

evolutionary processes that are governed by God”). The well-known evolutionary biologist Dobzhansky expressed this kind of position in his famous paper (1973: *Nothing in Biology makes sense except in the light of Evolution*): “I am a creationist and an evolutionist. Evolution is God's, or Nature's method of creation” (p.127). This position is interesting in biology education, because it is not antievolutionist. More biology teachers than their non-biologist colleagues ticked this item, being believers and practising religion, but also evolutionist. In some countries, as in France and in Scandinavian countries, several teachers are simultaneously believers in God, practising religion and ticking the items 1 or 2 of the question B28, items that are clearly evolutionist.

6 – Discussion and conclusions

Few studies have analyzed the perception of evolution at an international level. The largest and most known inquiry was published by Miller, Scott & Okamoto (2006) and compared the public acceptance of evolution in 34 countries, showing the minimum of acceptance in Turkey (25% of adults agreed with the proposition “*Human beings, as we know them, developed from earlier species of animals*”) and in US (40%). From a sociological study (Hassan, 2007) including only one question related to evolution (“*Do you agree or disagree with Darwin's theory of evolution?*”) Hameed (2008) published that 22% of Turks, 16% of Indonesians, 14% of Pakistanis, 11% of Malaysians and 8% of Egyptians agree, while 40% in Kazakhstan.

Working with teachers to analyze their problems and to suggest propositions to improve their training, the Biohead-Citizen research is also innovative for three other reasons:

- The quality of the questionnaire, with 14 questions related to Evolution, certain questions allowing the responder to say he / she is at the same time evolutionist and creationist, and also with several questions related to the four other topics of this project of research (genetic determinism, environmental, health and sex education), allowing correlations of responses to identify the teachers' systems of conceptions.
- The identity of samples in each country: the same categories and numbers of teachers; each teacher's personal information including his / her socio-political and religious opinions. In consequence, this allows rigorous comparisons and the identification of possible correlation between the teachers' conceptions of evolution and some of their personal characteristics.
- The diversity of countries: diversity of economical development, of geographical location, as well as of religion (depending the country, mainly Catholic, or Protestant, Orthodox, Muslim or also Agnostic / Atheist). Several of them were included for the first time in this kind of international comparison.

The large volume of the Biohead-Citizen data needs successive complementary analyses and publications. Some analyses related to evolution are further developed from a limited number of countries (12 to 19 countries: Quessada et al 2007, Quessada 2008, Quessada & Clément 2011, Clément & Quessada 2008, 2009, 2012) and we will publish soon a more complete presentation from 28 countries. The present work is the first to be focused in 21 countries on the analysis of teachers' conceptions on chance and determinism in evolution.

The correlation between the acceptance of creationism and the high degree of belief in God and practice of religion, illustrated here by the Figure 7, was already known from our first comparisons of 12 to 19 countries. It is not a surprise to find it again from 21 countries. This influence of religion on the revival of creationism is presented and discussed in several articles and books: among others, Jones & Reiss (2007), Coquidé & Tirard (2008), or Portier,

Veuille & Willaime (2011). Less work paid attention to the teachers' difficulty: for instance in U.K. (Reiss 2008), in Brazil (El-Hani & Sepulveda, 2010) or in Lebanon (BouJaoude et al. 2009). Some authors, as Mahner and Bunge's (1996), or Dawkins (2006), argue that a person has to opt between a religious or a scientific perspective. Several others, as Cobern (1996) consider possible that a religious person develops a scientifically compatible worldview. Dobzhansky (1973) already claimed the same (see above). El-Hani & Sepulveda (2010) investigated the degree of compatibility between the worldview of Protestant biology pre-service teachers and scientific ideas related to evolution.

The results presented here confirm that an important amount of teachers believing in God, practicing religion (Figure 7-P12b) and believing in the importance of God in species evolution (Figure 6) are also evolutionist (figure 7-B28). A large majority of them, moreover, agree with the importance of natural selection for species evolution (Figure 4): even in Algeria, half of teachers answered "great importance" of natural selection in species evolution (Figure 4) while nearly all believe in God, practice religion (Figure 7b), answered "great importance" for God in species evolution (Figure 6), and more than 90% ticked the most radical creationist item for the origin of life and for the origin of humankind (Figure 7a), Nevertheless, only 10% of these Algerian teachers answered "great importance" for chance in species evolution.

In each country, comparing the Figures 3 and 4, less teachers ticked importance of chance than of natural selection in species evolution. Even in France, where almost teachers are evolutionist, 10% of biology teachers and 20% of non-biology teachers ticked no or few importance of chance.

The reluctance to accept the importance of chance is more important when dealing with evolution (Figure 3) than when dealing with the acceptance of a stochastic process as the sex of a child (Figure 5). There is indeed approximately the same ranking of countries in these two figures, but the amount of scientific error for the sex of a child is largely lower than for the role of chance in evolution, in each country.

Here is an illustration of the KVP model (Figure 1), the knowledge (K) of some teachers interacting with the values (V) and practices (P) of their religion. They accept a process by random, by chance, when it is related to the sex of their child, and not in contradiction with their religious beliefs. In contrast, several of them do not accept the importance of chance in evolution, because their religion claims that the fine adaptations of life cannot emerge from a "blind chance", and consequently would necessarily be the result of God's design. The trap of this alternative is analyzed by Clément (2002) in some Christian (Jehovah's Witnesses, 1985) as well as Muslim discourses (Keskas, 1996): the eventual role of chance in evolution is the main target of attacks, ignoring that the scientists never reduced evolution to chance, the emergence of new species becoming from the articulation between chance (stochastic processes of differentiation by mutations, genetic drift, ...) and natural selection. In these texts, there is no attack against the notion of natural selection, that can explain its widely acceptance by teachers practicing religion.

Finally, to take into account the different meanings of conceptions presented in the Table 1, we can say that in a first time our work presents situated conceptions of teachers, related to each single question. In a second time, we analyze the convergence between these answers, showing that teachers' conceptions are more or less evolutionist or creationist. We illustrated this convergence by some figures related to some questions, but all the answers to the five questions related to this topic are convergent, and also correlated with the answers to the

questions related to a possible goal-ended evolution. In other words, there are two poles inside the teachers' conceptions, the most evolutionist one disagreeing with a goal-ended evolution, and agreeing with the importance of chance in species evolution, and the most creationist one having the inverse positions. In a third time, we correlated these types of conceptions with the nationality, or with the degree of belief in God and of religious practice, showing that evolutionist as well as creationist conceptions can be defined as social representations. In a fourth time, not presented here but starting to be analyzed in another publication (Clément et al., 2012), we can correlate these social representations related to evolution with those related with another topic, as the genetic determinism of some socio-cultural human features (e.g. housekeeping by women), putting in evidence "*systems of conceptions*". The most creationist conceptions are correlated with a strong belief in a biological determinism of these human features.

Last point, the comparison between biology teachers and their colleagues shows that, in half of the analyzed countries, training in biology increases the percentage of evolutionist conceptions and of acceptance of the importance of chance in evolution. We can conclude with the necessity of training more and better teachers. Nevertheless, it will be difficult to change the teachers' conceptions, because they are not rooted only in out-dated or up-to-date knowledge, but also in their values and social practices.

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